Optical Wave Guide Sensor for Structure Health & Damage Assessment

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Dr. Everett E. Crisman

Scientist

SNHA

Air Force Research Laboratory

Contributors

Everett E. Crisman & John S. Derov
Air Force Research Laboratory
Hanscom AFB, MA

* Otto J. Gregory & William B. Euler
University of Rhode Island
Kingston, RI

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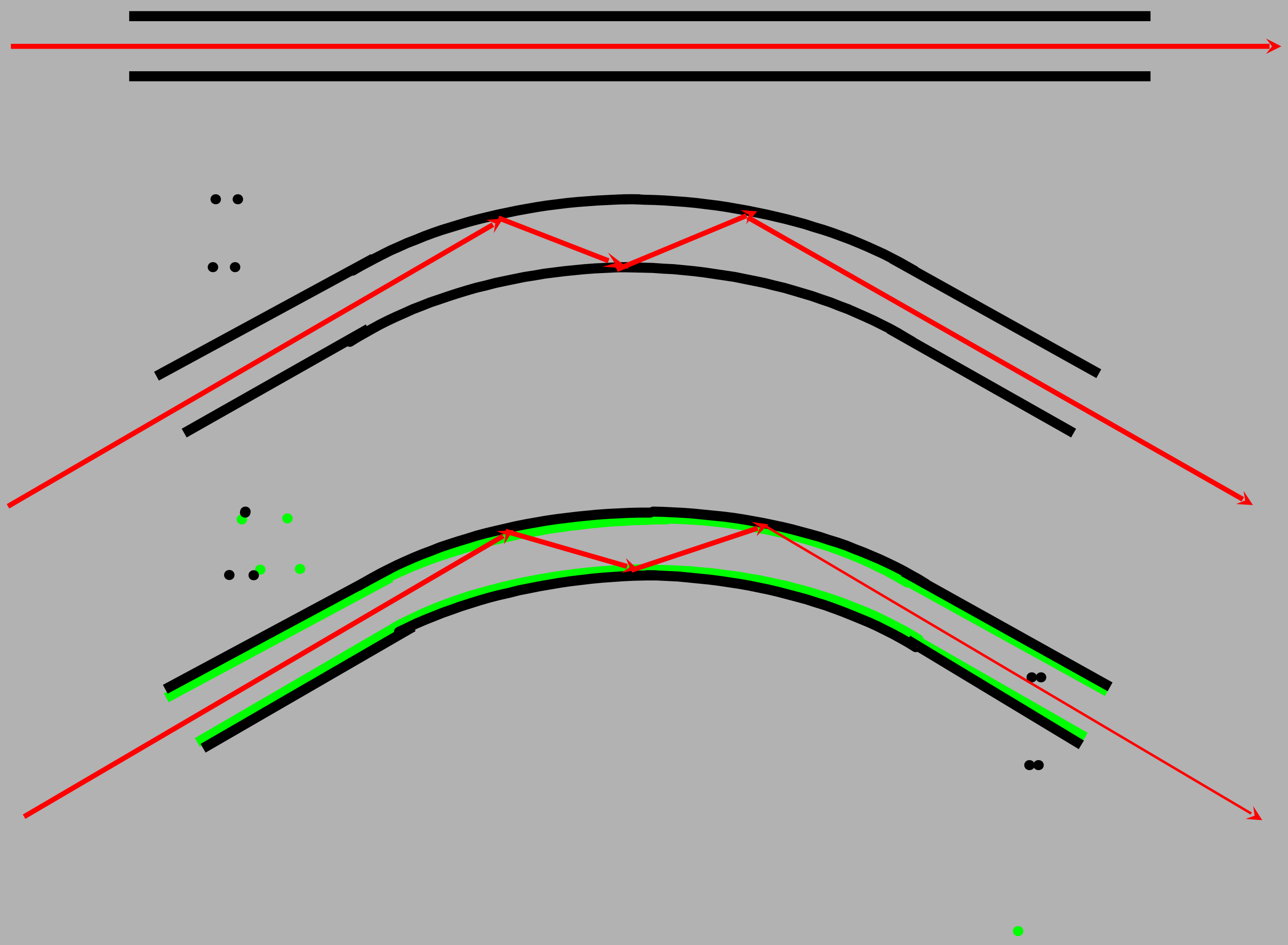
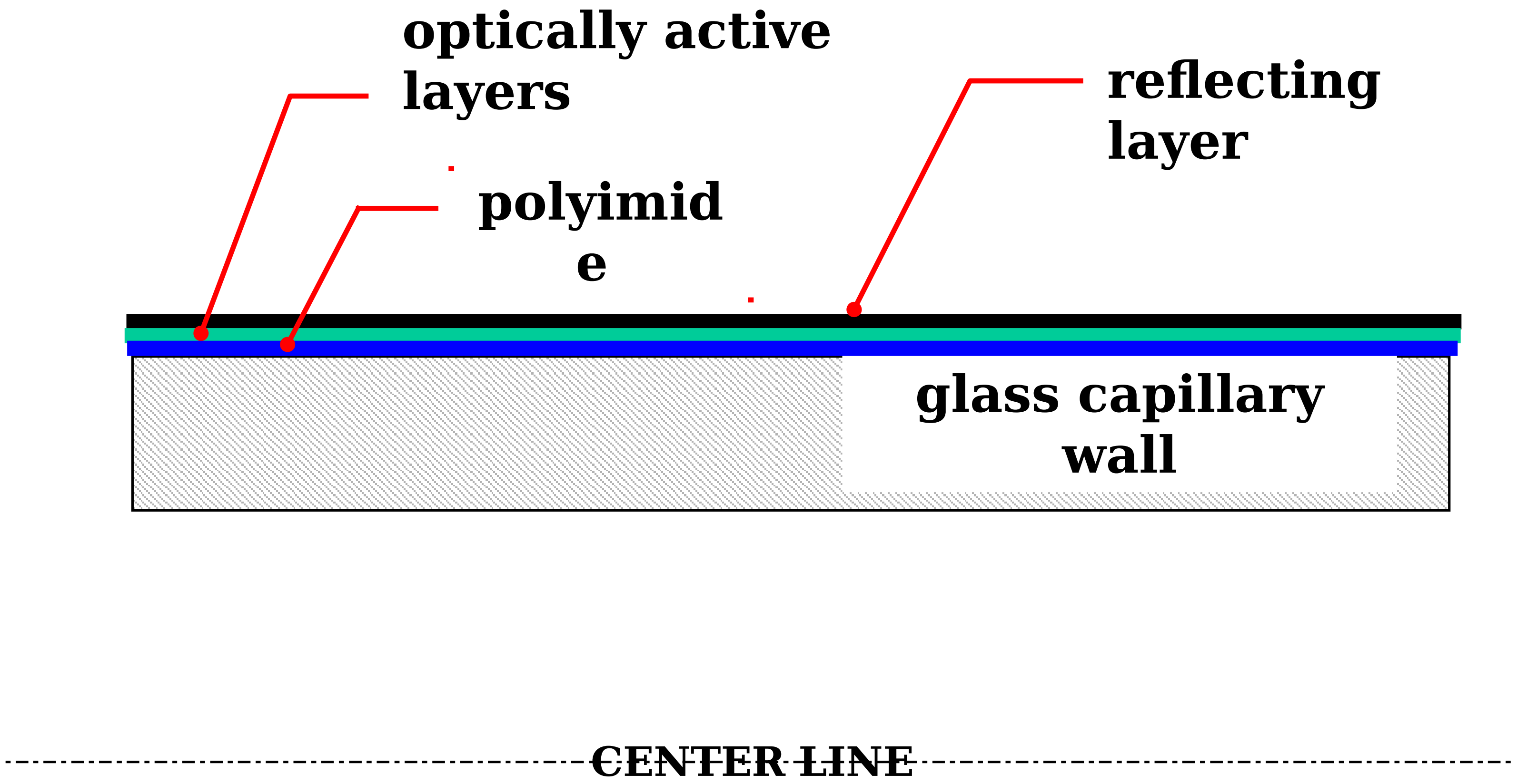
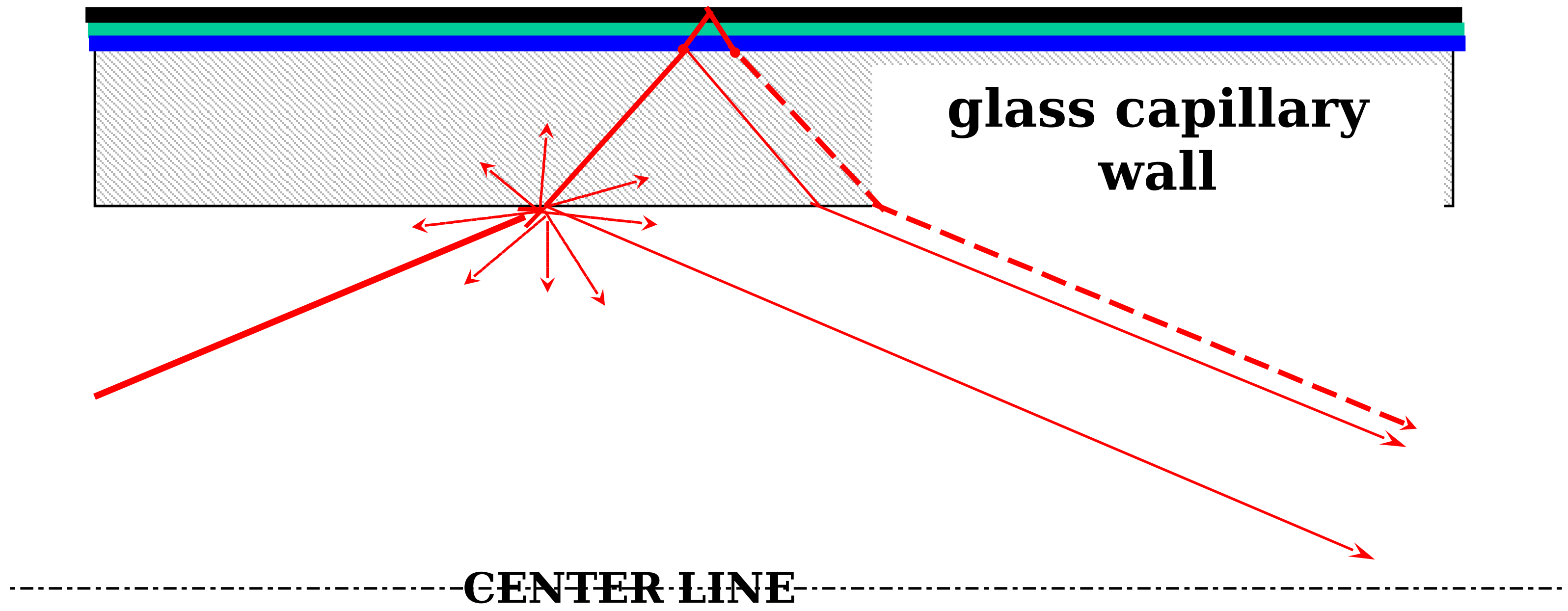
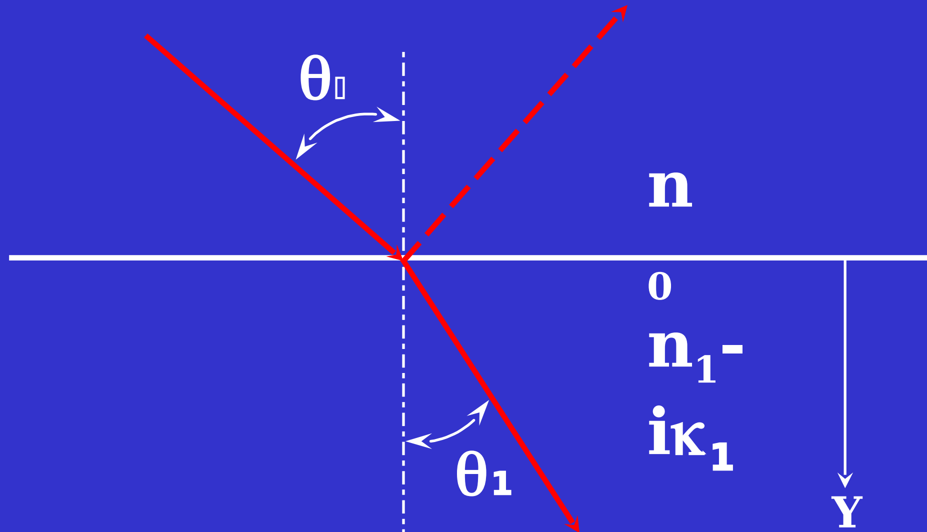
BASIC CONCEPT




optically active layers
polyimide
reflecting layer
glass capillary wall
CENTER LINE



SINGLE LIGHT BEAM/WAVE-GUIDE INTERACTION EVENT



$$\rho = \left[\frac{n_1 - n_0}{n_1 + n_0}\right]^2$$

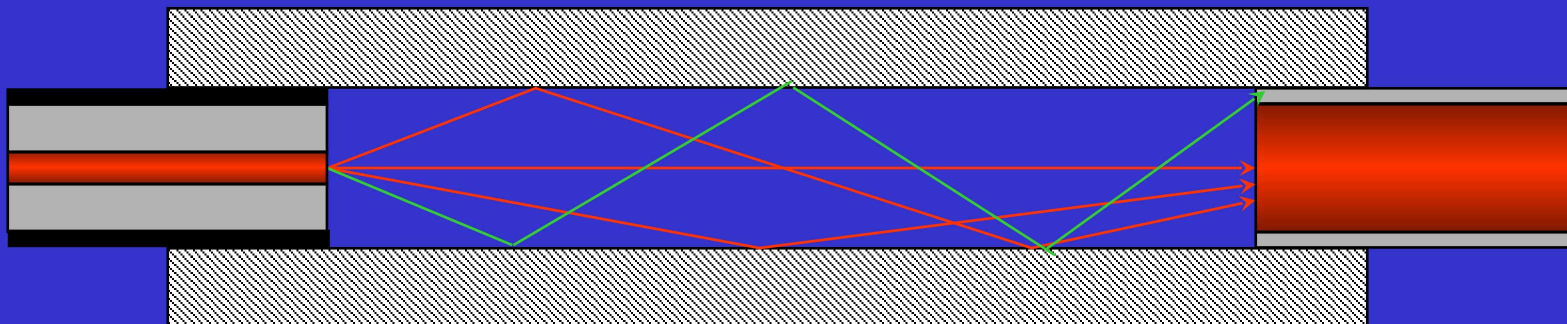
Fresnel's Law (reflection)

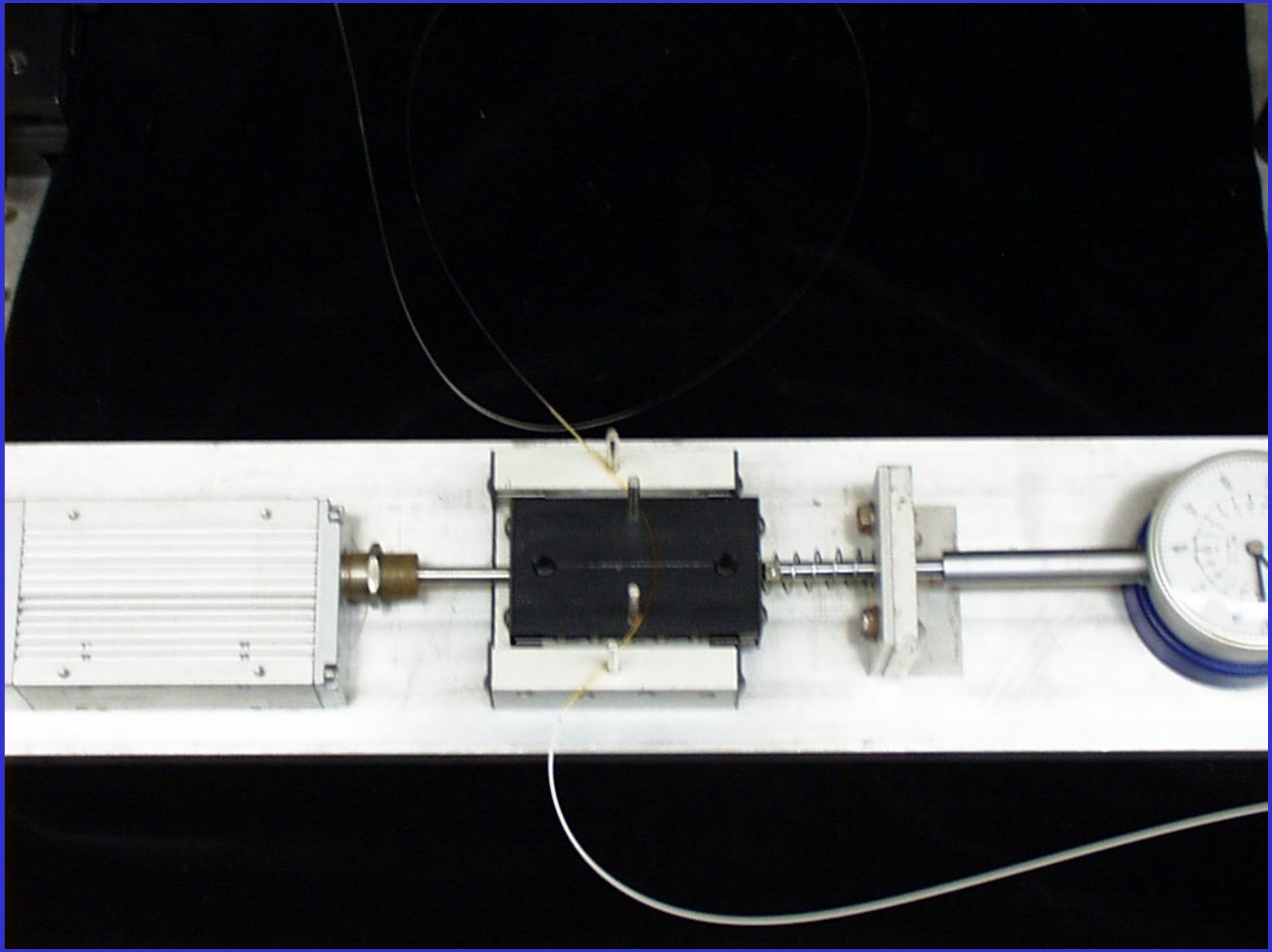
$$n_1 \sin\theta_1 = n_0 \sin\theta_0$$

Snell's Law

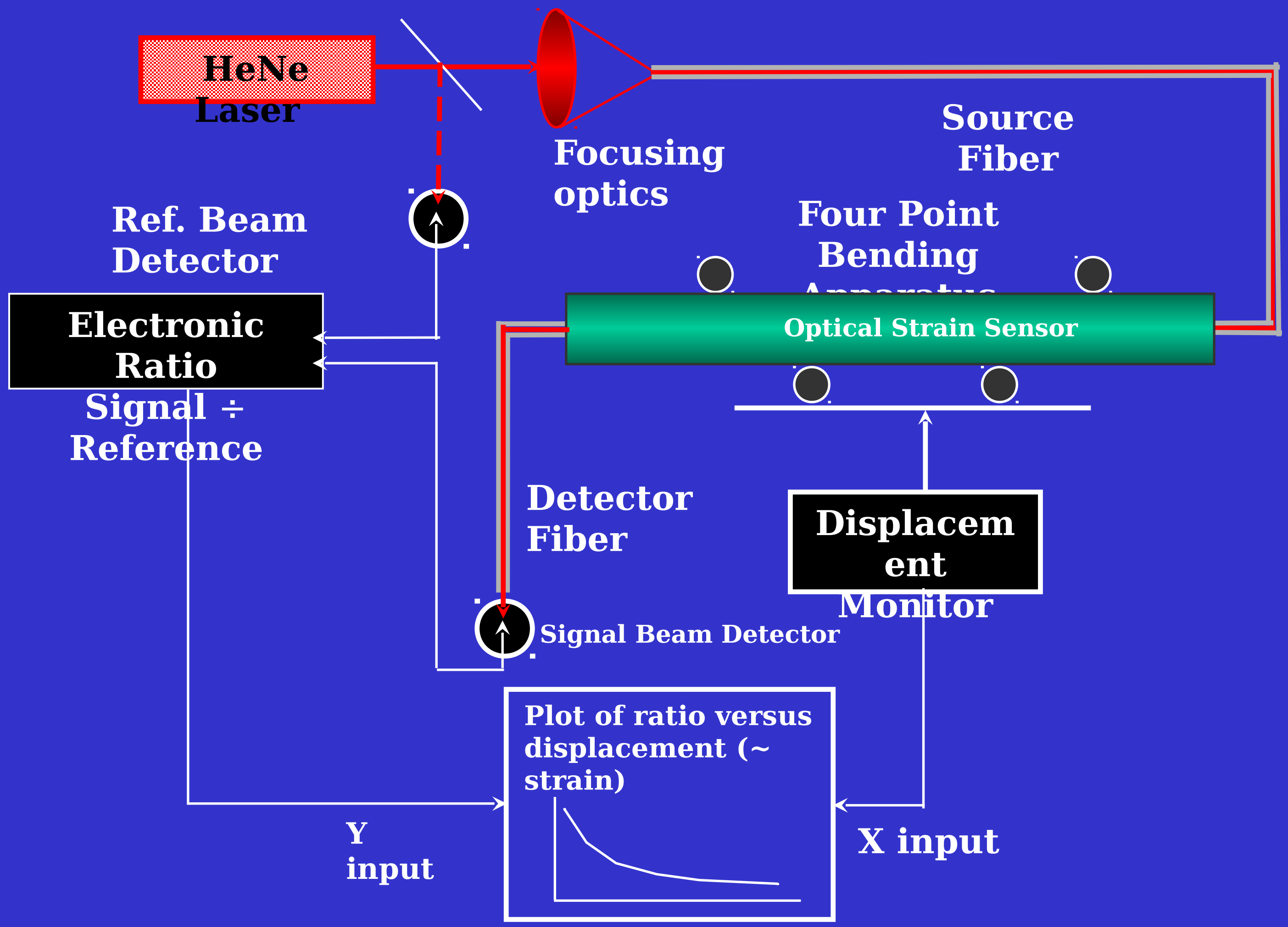
$$I(y) = I_0 e^{-\alpha y}$$

Absorption ($\alpha = 4\pi\kappa/\lambda$)

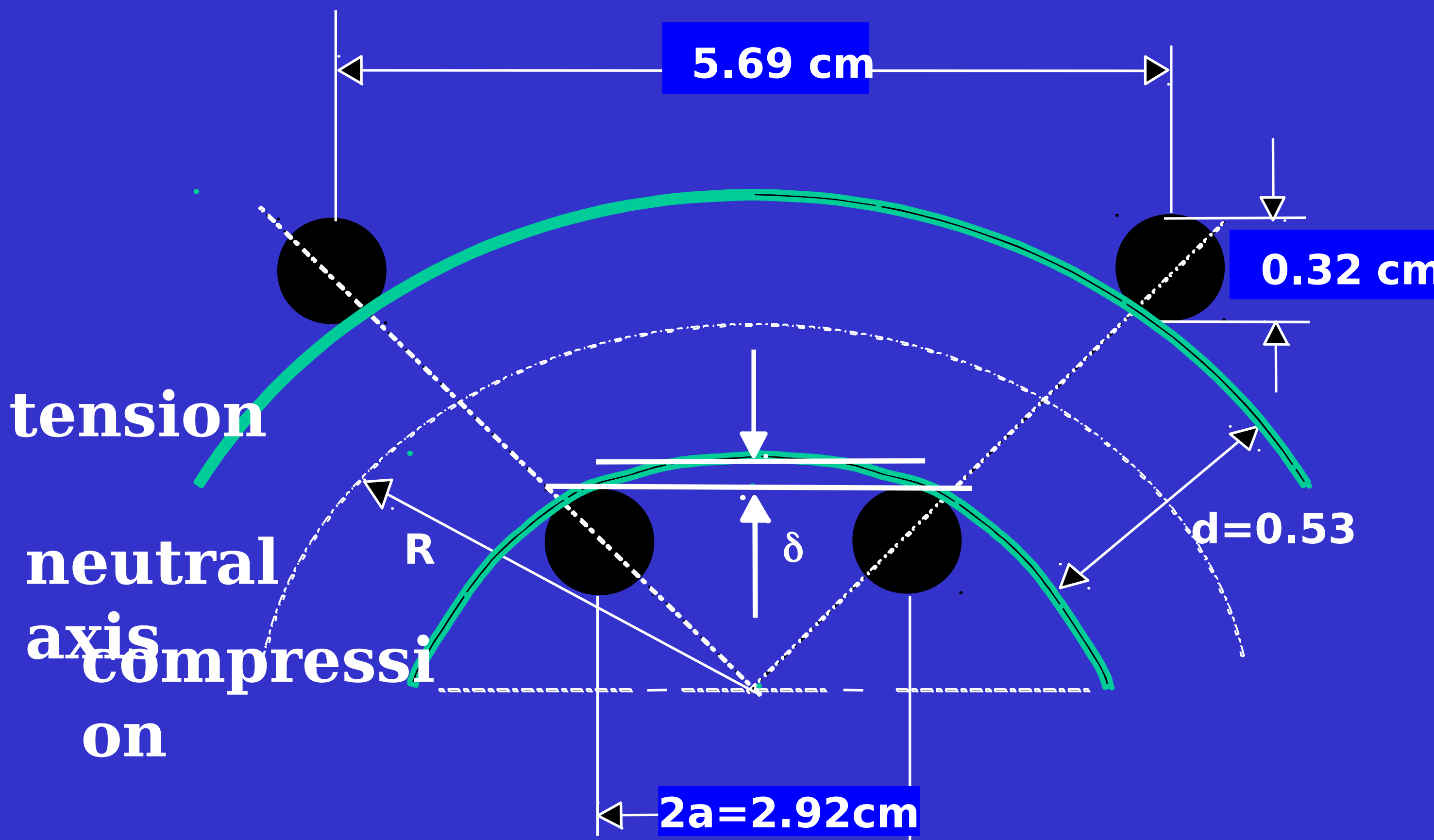





ORIEL



HeNe Laser
Focusing optics
Source Fiber
Ref. Beam Detector
Four Point Bending Apparatus
Electronic Ratio Signal ÷ Reference
Optical Strain Sensor
Detector Fiber
Displacement Monitor
Signal Beam Detector
Plot of ratio versus displacement (~ strain)
Y input
X input



Four Point Bending

Strain as a function of δ: $\varepsilon = \dfrac{2\delta d}{a^2 + \delta^2}$

Bend radius as a function of strain: $R = \dfrac{d}{2\varepsilon}$

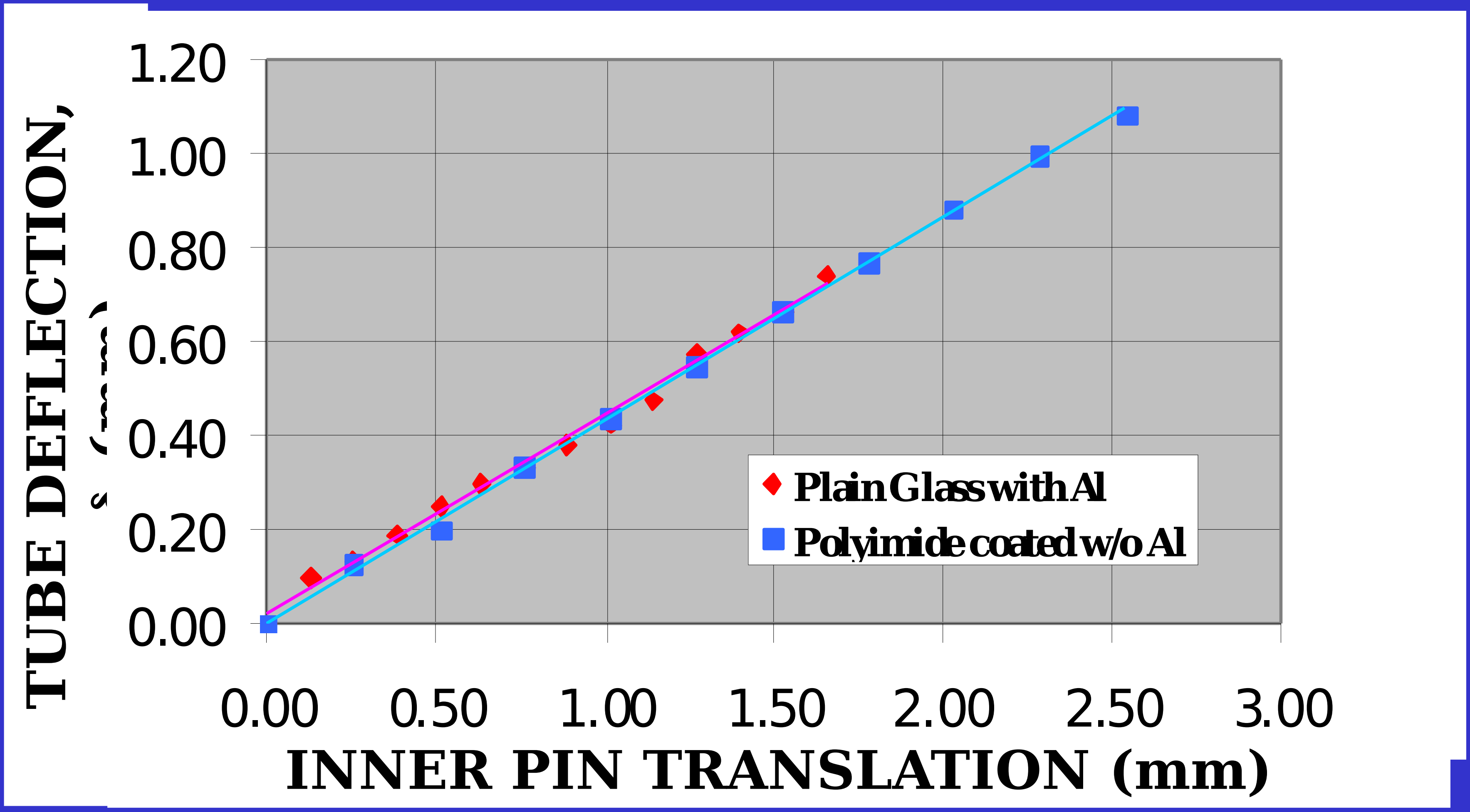
Number of 'bounces' as a function of bend radius

For principal ray, N_0:

$$N_0 = 1 + \frac{L}{2(R - d/2)\cos\left[(R - d/2)/R\right]}$$

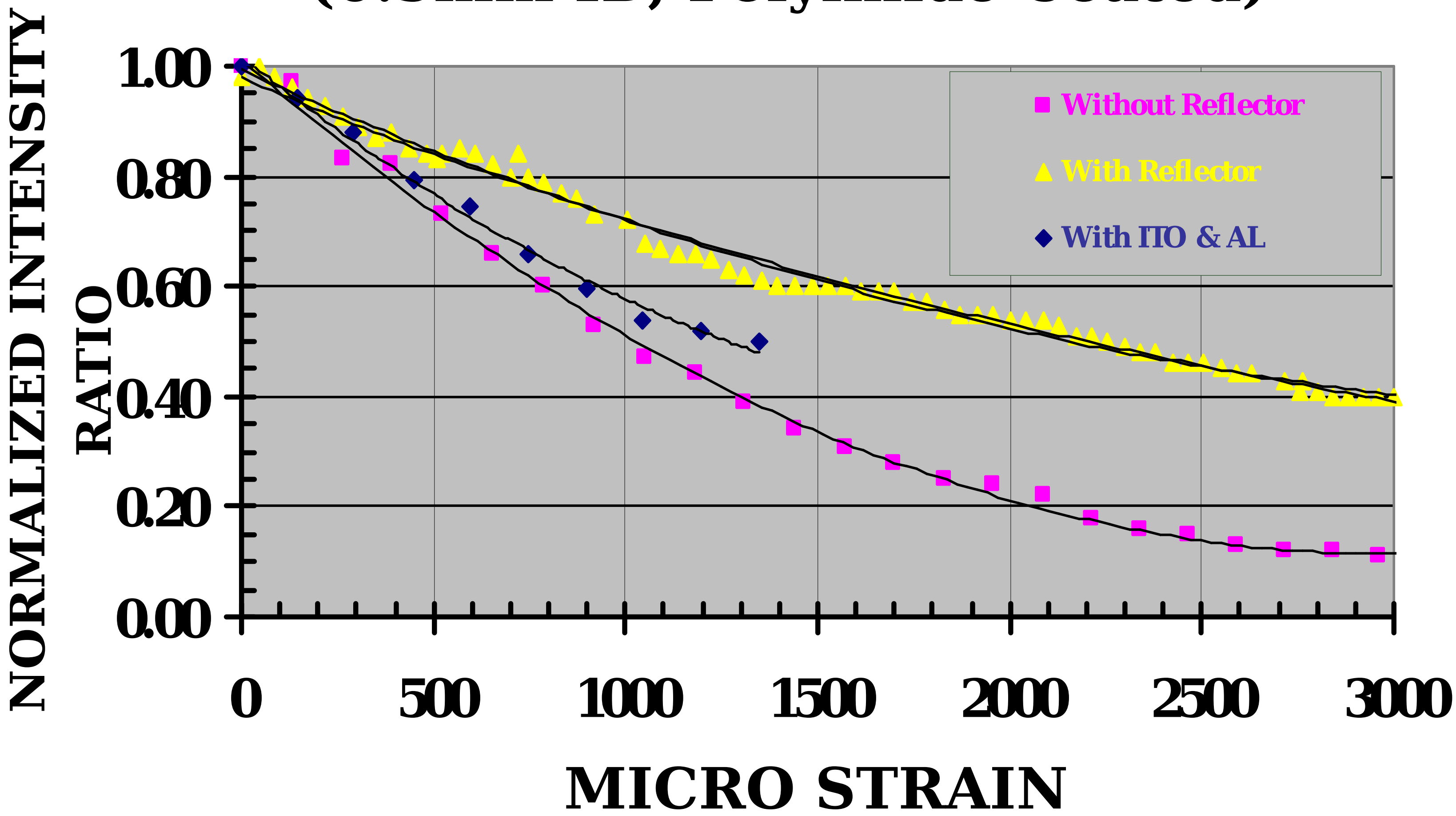
Gage Factor: $G = \dfrac{1}{I_0} \cdot \dfrac{\Delta I}{\Delta \varepsilon}$

δ vs Pin Translation
(0.5 mm ID)

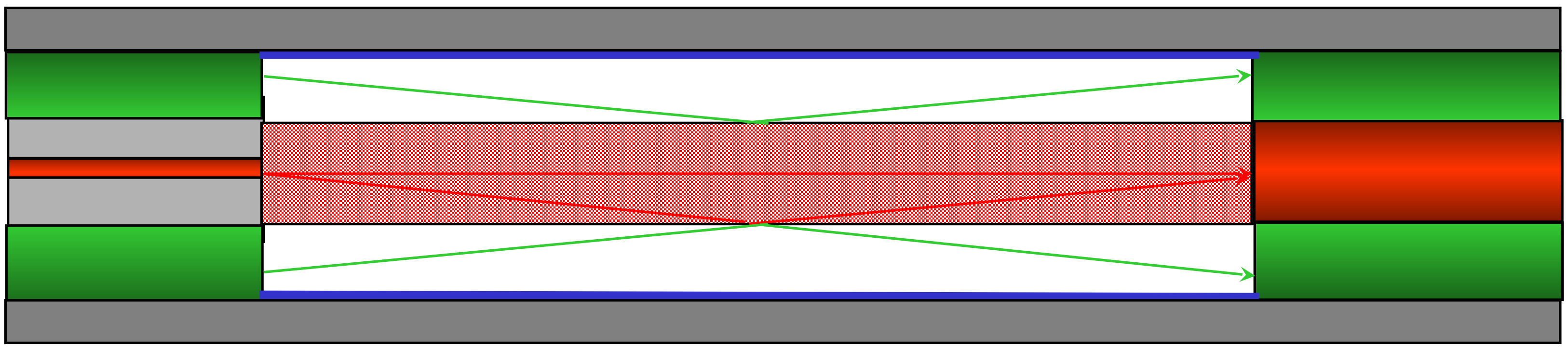


From K. Thomas et al.

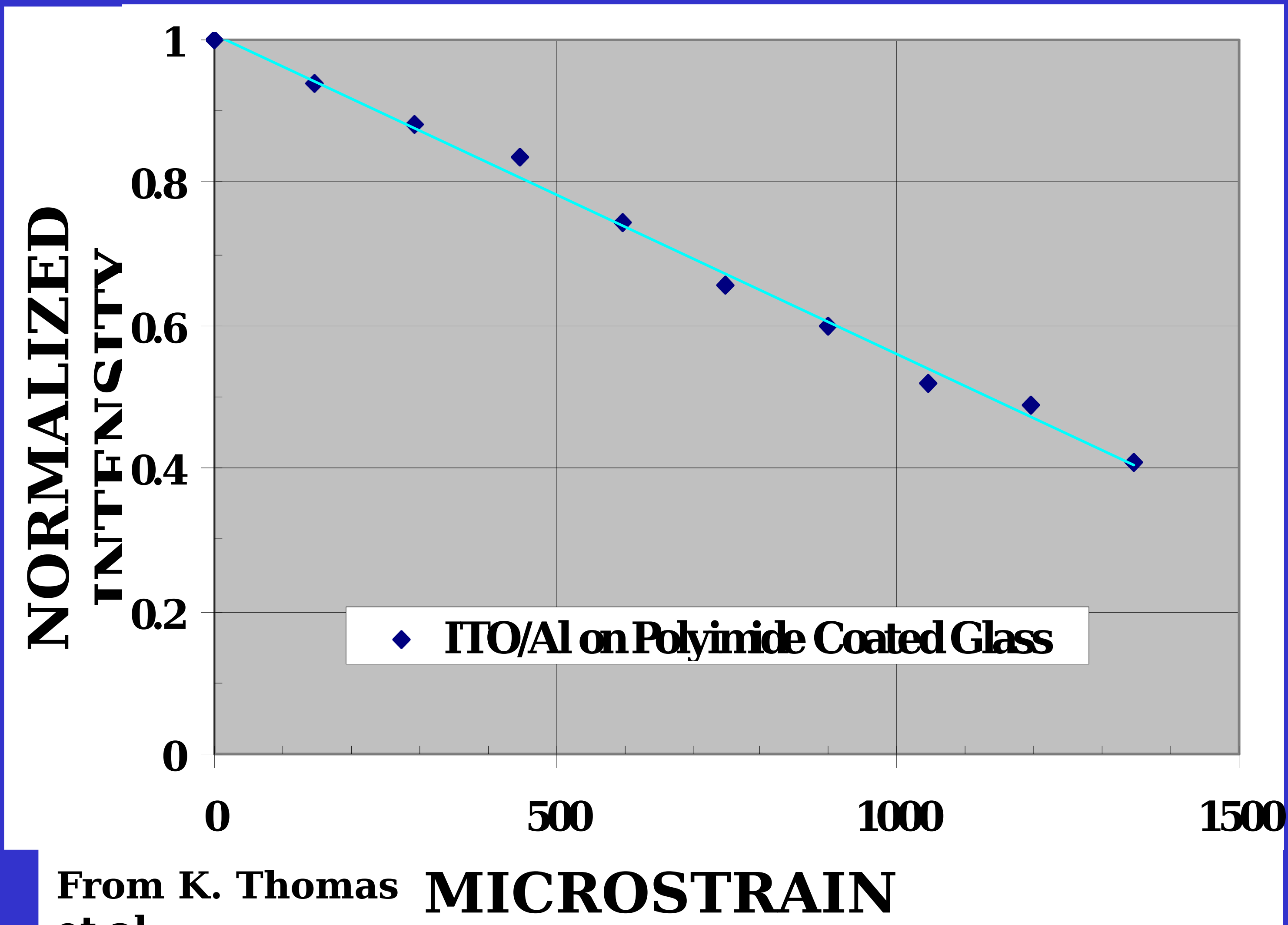
Intensity Ratio vs Strain
(0.5mm ID, Polyimide Coated)



K. A. Thomas, E. E. Crisman, W. B. Euler and O. J. Gregory
Proceedings: SPIE Smart Structures and Materials 2000: **S. C. Liu, ed., SPIE Press, v3988, p429 (2000)**



Intensity Ratio vs Strain
(with ITO layer)



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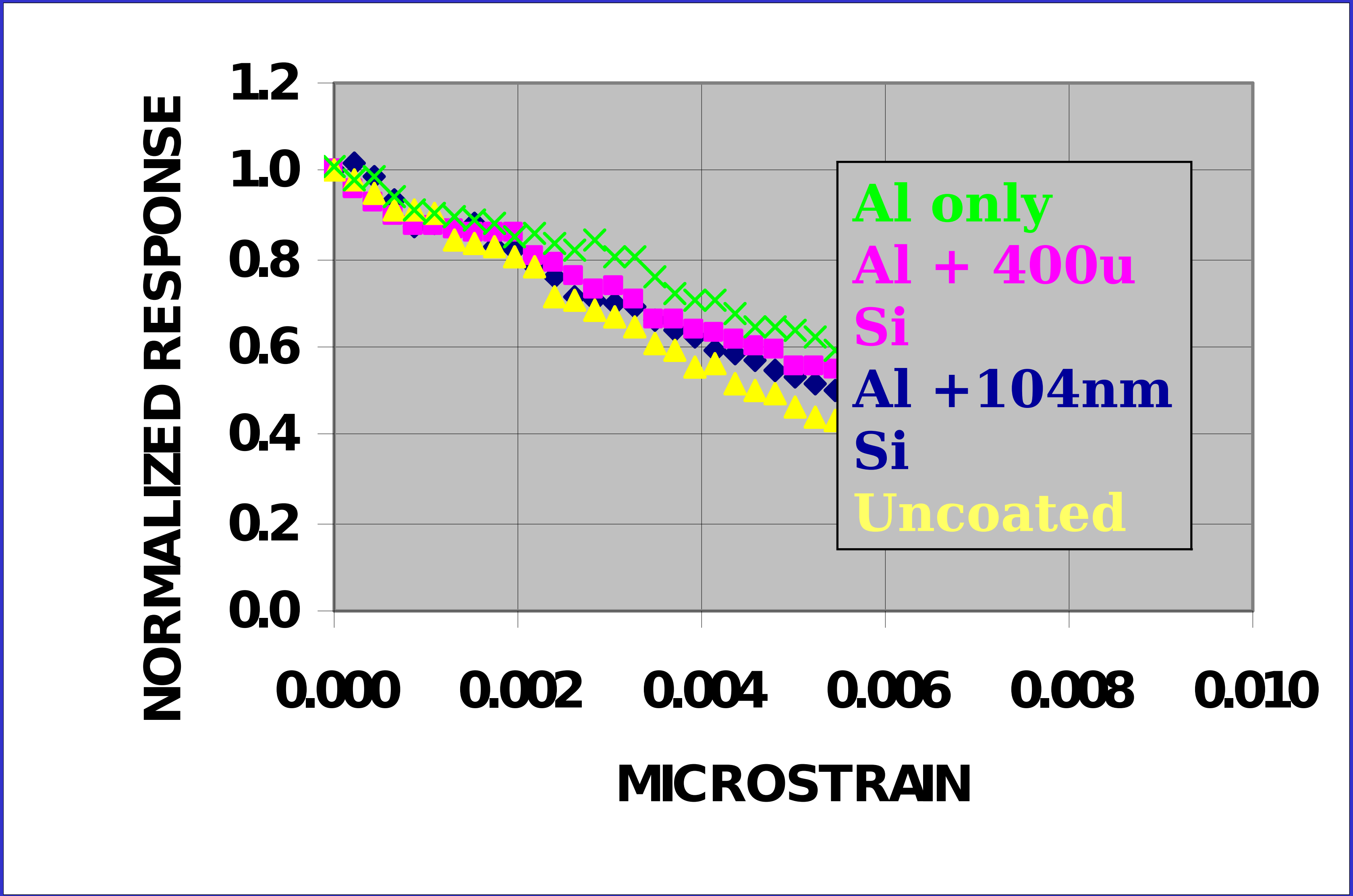
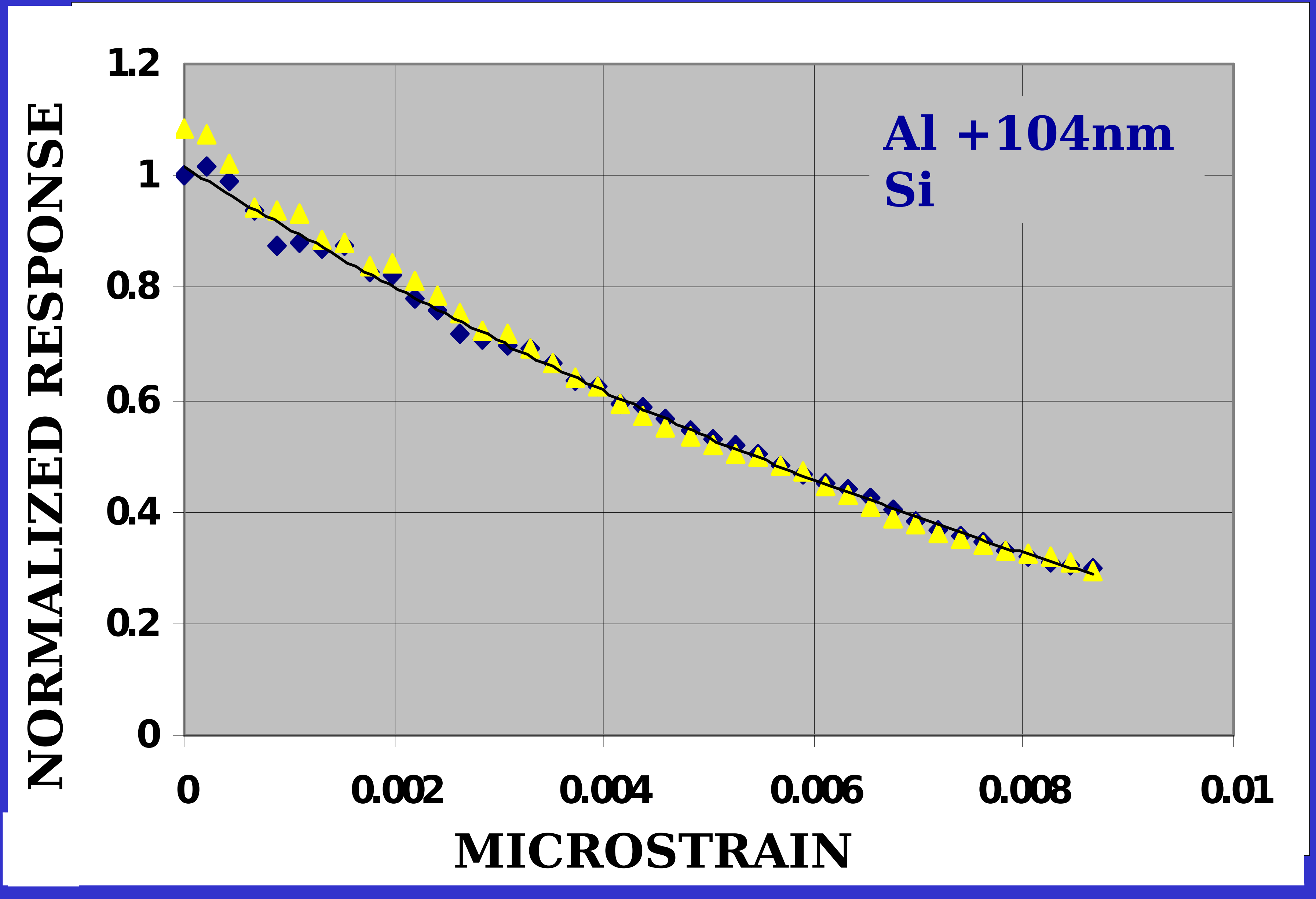


NORMALIZED RESPONSE
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.000
0.002
0.004
0.006
0.008
0.010
MICROSTRAIN
Al only
Al + 400u Si
Al +104nm Si
Uncoated



NORMALIZED RESPONSE
1.2
1
0.8
0.6
0.4
0.2
0
0
0.002
0.004
0.006
0.008
0.01
MICROSTRAIN
Al +104nm
Si

Sensor	Signal Strength (I/I_0)	Gage Factor
Polyimide/Al	$8.8x10^{-2}$	69.7
Polyimide/Al/40nm Bi	$6.92Ex10^{-2}$	70.4
Polyimide/Al/104nm Bi	$4.37x10^{-2}$	92.3
Polyimide coated only	$4.14x10^{-4}$	109.6

SUMMARY

- **Large, adjustable gage factors; >100**
- **Reproducible to 8000 micro-strain**
- **Easily adaptable to optical fiber data systems**
- **Robust**
- **Chemically Stable**
- **Simple & cheap material and design**
- ***Capable of both active *and* passive strain measurements.***
- ***TEMPERATURE INSENSITIVE***